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Late Pleistocene Invertebrates from Punta Cabras, Baja California, Mexico

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INTRODUCTION

A prominent terrace platform mantled by richly fossiliferous sand of late Pleistocene age and alluvial deposits is well exposed in sea cliffs in the vicinity of Punta Cabras, some 40 miles south-southeast of Ensenada, Baja California, Mexico. This area (latitude 31° 20′ N.) lies at the northern end of an extensive wave-cut platform which can be traced at least 31 miles along the coast to Punta San Telmo (Beal, 1948). At Punta Cabras the thin mantle of terrace deposits has yielded a collected fauna of 107 marine invertebrates, chiefly mollusks. This assemblage lived in a shallow-water, near-shore environment bordering an open, precipitous coast. Interpretation of modern latitudinal ranges of component species indicates a significantly colder hydroclimate than exists at this latitude today. The configuration of the late Pleistocene coast and the development of associated submarine erosional platforms, principally in areas between rocky points, were controlled largely by the resistance of Cretaceous rock units to the erosional action of waves. Thus the old shore line essentially parallels the modern one, extending somewhat farther inland into outcrops of less resistant Cretaceous rock.

The present paper is presented in order to describe and discuss in terms of the Quaternary history of this region the occurrence of the

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open-coast, cool-water facies at Punta Cabras. The Punta Cabras fauna extends the known distribution of this fossil facies southward from the Punta China area (fig. 1). An ecologically comparable assemblage occurs at Punta Baja, some 95 miles southeast of Punta Cabras. Of considerable paleogeographic importance, therefore, is the intervening location of the warm-water, protected-bay fauna at San Quintín Bay (see fig. 1 for localities mentioned).

The Punta Cabras area was first visited by the writers during a larger reconnaissance of accessible late Pleistocene terrace deposits from the San Diego area to Punta Baja (latitude 32° 32′ N. to 29° 57′ N.) during the winter of 1952–1953. Our attention was drawn to this area by Dr. Carl L. Hubbs who had previously located areas of abundantly fossiliferous terrace sands and kitchen-midden deposits along the coast while making a series of near-shore temperature surveys. Fossil collections were supplemented by additional collecting by the junior author during two subsequent trips.

Punta Cabras is reached by traveling south on the peninsular highway from Ensenada to San Vicente. From this point a poorly maintained side road follows the San Isidro River to the coastal villages of Ejido Erendira (Gerhard and Gulick, 1956) and San Isidro. A "jeep" trail follows the coast northward for 6 miles, terminating at a seasonally operated lobster fishing camp north of Punta Cabras.

The terminology used in the description of terrace features is explained diagrammatically in figure 4.

Previous Work

Recent investigations of late Pleistocene terrace faunas from northern Baja California have provided a framework within which regional paleoecologic interpretations, especially of water-temperature distribution, can now be made. For several years the exhaustive literature of the late Pleistocene faunas of southern California was complemented by published descriptions of only one locality from the northwestern coast of Baja California, the classic San Quintín fauna of Jordan (1926), Manger (1934), and others.

Despite infrequent local occurrences of relatively cool-water assemblages, the warm-water aspects of invertebrate collections from some horizons in the Los Angeles basin and coastal San Diego regions have been clearly demonstrated (Woodring *et al.*, 1946). Apparently correlative marine deposits on the Santa Barbara coast, nearly 100 miles northwest of Los Angeles, have yielded faunas that indicate water temperatures slightly colder than present ones. The San Quintín

fauna contains warm-water elements in common with the late Pleistocene Palos Verdes sand of the Los Angeles basin which are indicative of comparable or warmer water temperatures. Based on a consideration of the Santa Barbara, Los Angeles, San Diego, and San Quintín faunas, a progressive increase in ocean temperatures to the south during late Pleistocene time seemed apparent. Thus, warm-water conditions were postulated between the Nestor terrace deposits of the San Diego region (Ellis and Lee, 1919) and San Quintín, some 150 miles to the southeast.

Faunas recently described from the northwest coast of Baja California (Emerson, 1956b, and Valentine, 1957) show that water temperatures generally lower than those currently existing at the same latitudes prevailed during the late Pleistocene. Consideration of the paleogeography of late Pleistocene physiographic elements and related fossiliferous deposits provides a satisfactory explanation for many of the apparently anomalous occurrences of cool-water faunas along the Baja California and southern California coasts. Without exception, these faunas lived in shallow water adjoining areas of predominantly rocky, open coast. Faunas containing warm-water indicators developed in late Pleistocene bays or in protected bay-like areas in the lee of offshore islands such as the low volcanic cones west of the San Quintín locality.[1] If the warm-water facies was limited to shallow bays and lagoons, its distribution was discontinuous, but the facies of cooler water apparently was developed more or less continuously in littoral and upper neritic waters along the open coast. At certain localities "mixed faunas" containing elements from both facies have been described (Woodring *et al.*, 1946).

Acknowledgments

It is a pleasure to acknowledge the aid received during the progress of this study. Assistance in the field work was given during three visits to the area by several of our former associates at the University of California Museum of Paleontology, the sponsor of the field investigations. Various kinds of contributions were made by the following persons during the early stages of this study: Drs. E. Yale Dawson,

[1] It is notable that Hanna (*in* Jordan, 1926) remarked that fossils from these exposed Pleistocene islands differed in kind from those at the San Quintín locality. Presumably these undescribed forms represent the cool-water, open-coast facies. Webb (1937) recognized that faunas from the windward side of Point Loma, near San Diego, California, represented a cooler-water facies than collections from the protected-bay side described by Arnold (1903) and others.

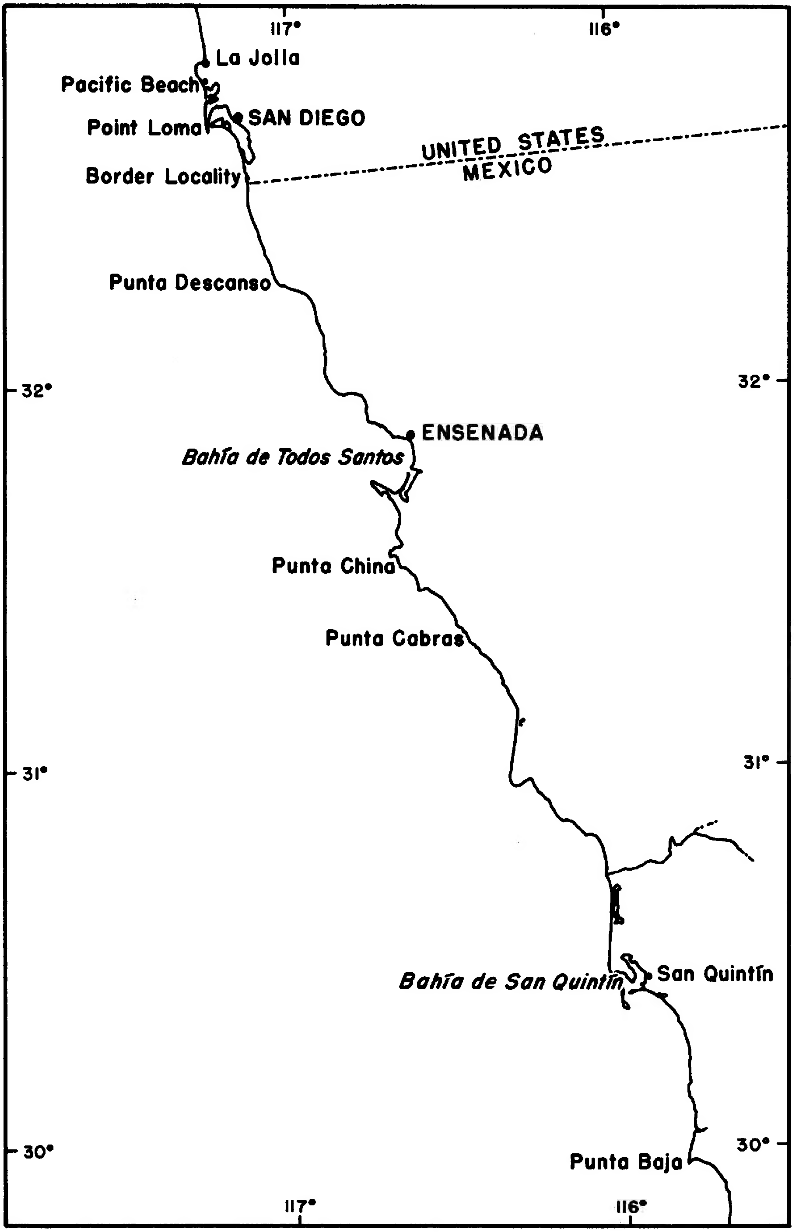

FIG. 1. Map showing location of the principal localities mentioned in the text.

J. Wyatt Durham, Carl L. Hubbs, Leo G. Hertlein, Robert M. Kleinpell, and R. A. Stirton. We are particularly indebted to Mr. Millis H. Oakes for allowing us to reproduce his field map of the Punta Cabras area. Dr. J. Wyatt Durham, Dr. Donald E. Savage, and Mr. John G. Vedder kindly read the manuscript and offered helpful suggestions. The writers, however, accept full responsibility for the views expressed in this paper.

GEOLOGIC SETTING

Beal's (1948) 1:1,000,000 reconnaissance geologic map of the Baja California Peninsula shows that sediments of the Paleocene-Eocene Tepetate formation outcrop in the Punta Cabras-San Isidro area. Kirk and MacIntyre (1951) first reported Cretaceous sediments in the vicinity of Punta Cabras. A lower unit of predominantly volcanic rock was referred to the Alisitos formation; an upper sandstone and conglomerate unit of upper Cretaceous age was assigned to the Rosario formation.

Oakes (MS) made a detailed geologic-topographic map (scale: 1 inch = 1000 feet) of the Punta Cabras area (fig. 3). Two Cretaceous units were mapped: the San Fernando formation (= Alisitos formation of other investigators)[1] and the Rosario formation. The San Fernando formation consists of andesitic flows and pebbly tuffs intruded by diorite dikes. The Rosario formation was divided into three units: (1) a thin basal conglomerate deposited upon an irregular depositional surface eroded into the San Fernando formation, (2) a gray and green pebbly sand of undetermined thickness, and (3) a yellow silty sand about 60 feet thick. Dips measured in the Rosario formation seldom exceed 10 degrees, yet the underlying San Fernando formation is folded into a syncline trending northeast-southwest beneath the Punta Cabras upper Cretaceous embayment (Oakes, MS).

The patchy distribution of mildly deformed outcrops of Rosario formation along the northwest coast of Baja California has been interpreted as reflecting deposition in restricted embayments along an upper Cretaceous shore line which approximated late Pleistocene and modern coast lines (Langston and Oakes, 1954). A portion of one of these embayments is shown on the geologic map (fig. 3). Geologic

[1] The San Fernando formation was proposed by Beal in 1924 (Beal, 1948) for exposures of slate, conglomerate, limestone, and volcanic rock near San Fernando (latitude 29° 50′ N., longitude 115° 15′ W.). The Alisitos formation was later proposed by Santillán and Barrera (1930) for exposures of similar lithology near San Telmo (latitude 30° 56′ N.).

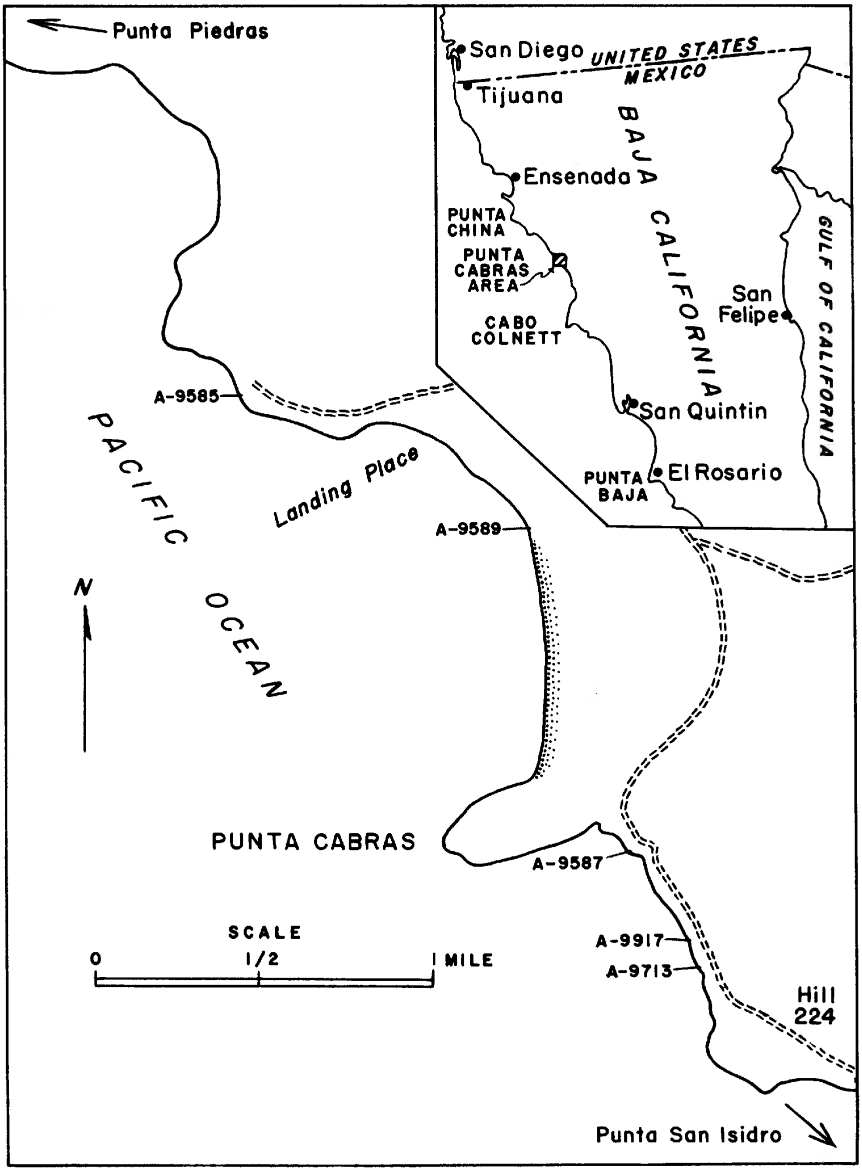

FIG. 2. Index map of the Punta Cabras area, showing approximate location of the principal collecting stations mentioned in text (sketch of the coast line enlarged from United States Hydrographic Office chart no. 1149).

mapping between latitudes 30° and 32° N. by Stehli and others (1958) demonstrates that volcanics, graywackes, and limestone of Albian age (Alisitos formation) are intruded by plutonic rock of the Baja California batholith. Both units are overlain unconformably by the Rosario formation of Maestrichtian age.

A thin mantle of late Pleistocene marine sand overlies the lowest submarine erosional surface cut into Cretaceous agglomerate, sandstone, and pebble conglomerate. Locally the Pleistocene strata overlie Cretaceous sandstone with apparent conformity (figs. 6, 8). Two older terrace surfaces at elevations of 150 to 250 feet and about 300 feet are shown by topographic contours on figure 3. Oakes (MS) described 15 feet of red, sandy, boulder conglomerate from the second terrace platform. No marine fossils were found on the higher terraces.

TERRACE PLATFORM

Description of Platform

From San Isidro northward to Punta Cabras the terrace surface is generally narrow. It is interrupted locally by steep headlands of resistant rock into which little or no bench was eroded. Form-line contours on the United States Navy Hydrographic Office San Diego to Bahia San Quintin chart (no. 1149) show the terrace surface broadening south of San Isidro. The United States Hydrographic Office sailing directions for the west coast of Mexico (1951, p. 33) describe this portion of relatively inaccessible coastline as ". . . a succession of broken bluffs and low beaches backed by small mesas [marine terraces] and these in turn by the coastal mountains about 2,000 feet high." At San Antonio River, 14 miles southeast of Punta Cabras, a "low and flat" plain extending some 4 miles inland is developed. The surface of the broad "plateau" of Punta Colnett limited by the San Antonio River on the north and San Rafael River to the southeast is listed as 300 to 400 feet in elevation (United States Hydrographic Office chart no. 1044-c). Apparently this is an older platform eroded during a higher stand of the Pleistocene sea.

The steep slopes of the resistant Alisitos formation which jut out to sea to form Punta Cabras apparently formed an upper Pleistocene promontory similar to the modern one. The erosive action of the Pleistocene sea is recorded prominently by terrace platforms developed in the local embayment of Rosario sandstone east and northeast of the Point. The crescent-shaped, wave-cut bench east of Punta Cabras abuts against more resistant Alisitos rock at Hill No. 224 on the

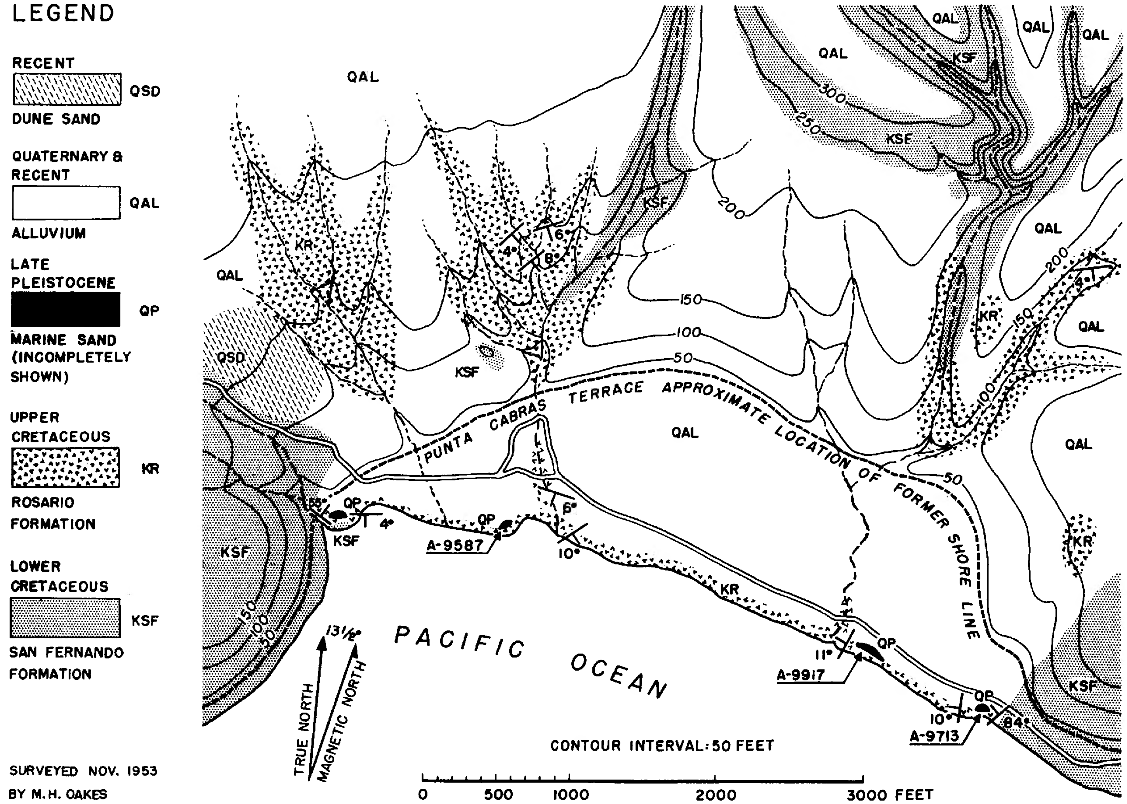

FIG. 3. Geologic map of a portion of the Punta Cabras embayment, showing location of the eastern part of the Punta Cabras terrace and the Pleistocene shoreline angle (modified after Oakes, MS).

south and Punta Cabras to the northwest (fig. 2). No platform was eroded into the rock on these promontories, but a narrow bench capped by marine deposits was cut into sediments of the Alisitos formation at locality A-9585 north of Punta Cabras.

Although a thin, non-marine, alluvial cover conceals most of the terrace platform, and the associated old sea cliff to the rear has been modified by erosion and mass movement, an interpolated shore-line angle was determined by the construction of profiles from the topographic map. The elevation of the former shore line is 50 feet above sea level. The base of the terrace platform exposed in sea cliffs occurs 12 to 20 feet above sea level. These, or even greater, differences in

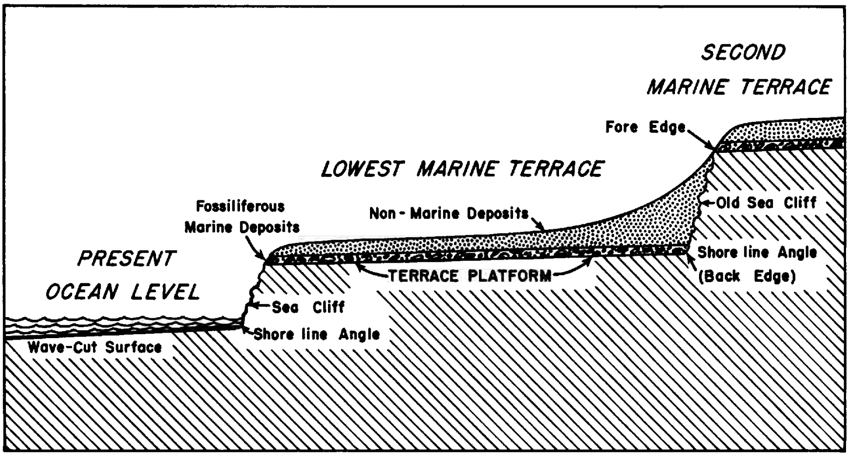

FIG. 4. Diagrammatic sketch showing terrace terminology used in the present paper.

elevations upon the wave-cut surface are controlled principally by distance from the former shore line and subjacent rock types.

Reference to figure 3, for instance, shows the late Pleistocene shore line approaching and joining non-terraced sea cliffs in areas of resistant Alisitos rock. The greatest width of the platform east of Punta Cabras is about 1500 feet. Over this distance the platform surface slopes gently seaward at a slope calculated at 1.5 degrees. Bradley (1957) determined comparable slopes of 0.5 and 1 degree for the submerged platform, 1.5 miles wide, off Santa Cruz, California.

In the Cape Region of the Baja California Peninsula, Hammond (1954) reported inner-edge elevations on the lowest terrace averaging 25 feet and ranging from 15 to 56 feet. At Punta China, 16 miles northwest of Punta Cabras, estimated elevations of the terrace plat-

form in sea cliffs range from 12 to 25 feet (Emerson, 1956b). Although definite data permitting interpolation of a shore-line angle are not available, the Punta China platform appears to be correlative with the Punta Cabras platform. Near Punta Descanso, some 75 miles to the north (Valentine, 1957), and at the International Boundary (Valentine, 1955), shore-line angles at elevations of 75 and about 85 feet, respectively, have been determined. At San Pedro, California, the shore-line angle of the first marine terrace is located between 85 and 100 feet above sea level.[1] Although definite conclusions must await accurate measurement and more detailed investigation, these data appear to be consistent with Emery's (1958) interpretation of down-warping of the submerged, wave-cut benches of the southern California borderland in a seaward or southwesterly direction from the Los Angeles basin.

Origin of the Terrace Platform

The Pleistocene epoch was initiated by profound climatic changes accompanying the development of continental ice sheets. Fluctuations in the amount of continental ice causing vertical oscillations of sea level appear to be the best explanation for the development of the low terrace platforms along the northwest Baja California coast. However, the possibility of tectonic control must be considered in areas of crustal instability such as the Los Angeles and Ventura basins. The Punta Cabras terrace is the local expression of one of a series of submerged and low-lying subaerial, wave-cut benches developed along the peninsular and southern California coasts.

The mechanism of platform cutting is abrasion caused by waves breaking in shallow water. The maximum "depth of vigorous abrasion" has been shown to be about 5 fathoms, or 30 feet (Dietz and Menard, 1951). Erosion of consolidated sediment and rock is greatest in the surf zone where most of the energy produced by breaking waves is spent. Below low-tide level, cutting proceeds at a slower rate. Wave and current action below this depth are capable of modifying only unconsolidated sediment. Diver observations of the sand-covered ocean floor off Los Angeles basin (Trask, 1955) suggest that little or no wave action occurs below about 60 feet.

Relief on the Punta Cabras platform amounts to about 30 to 35

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[1] On Second Street in San Pedro, Woodring (*in* Woodring *et al.*, 1946) has mapped the base of the Palos Verdes sand at an elevation of about 85 feet. Ground elevations at the back edge of this first terrace average about 100 feet. The shore-line angle, therefore, must be located between 85 and 100 feet.

feet, which indicates, within the above limits of marine abrasion, that the platform could have been eroded during a stationary period of raised sea level. Any greater vertical separation between elevations on the platform surface and the shore-line angle, evidence of which could possibly have been destroyed by retreating sea cliffs in Recent time, would necessitate a slowly rising sea level to cut the platform.

FIG. 5. *Left:* White, well-indurated, late Pleistocene coquina of comminuted shell material at locality A-9713. *Right:* Terrace platform exposed owing to differential erosion of the fossiliferous terrace deposits. Poorly consolidated, reddish brown alluvium and soil cover are visible at the break-in-slope above the fossiliferous bed.

Terrace Deposits

Fossil collections were made at five localities from the basal marine sand and gravel (fig. 2). The greatest observed thickness of marine sediment capping the platform was 4 to 5 feet. Locally, lenses of well-rounded Cretaceous sandstone boulders are developed at the base of the late Pleistocene sediments (fig. 6). Southeast of Punta Cabras a well-indurated, white-weathering coquina of comminuted shell material cemented with calcium carbonate overlies the terrace platform (fig. 7). Immediately north of the Point, the marine inundation is recorded by thin lenses of poorly consolidated, fine-grained sand and indurated

boulder conglomerate. In this area the terrace platform is pitted with vertical mollusk borings, many of which contain valves of *Schizothaerus* in place. Except for a relatively thick accumulation of wind-blown sand overlying locality A-9589, the greatest observed thickness of non-marine alluvial cover in the sea cliffs was less than 10 feet. Somewhat greater thicknesses of alluvium were noted by Oakes (MS) at the base of the old sea cliff east of Punta Cabras. The contact between marine and non-marine sediments is everywhere sharp and clearly defined by color change, textural contrasts, and distribution of shell material. Near the top of the alluvial cover, however, an extensive kitchen-midden layer of mollusk shells is incorporated in reddish brown soil exposed in the sea cliffs. The most common species observed in the middens were: *Mytilus californianus*, *Haliotis* sp., *Septifer bifurcatus*, *Lottia gigantea*, *Tegula funebralis*, and *Acmaea pelta*. Most of these constituents have been found in similar accumulations at Punta China (Emerson, 1956b) and Punta Descanso (Valentine, 1957).

A characteristic stratigraphic section of terrace deposits exposed in a sea cliff immediately north of Punta Cabras (locality A-9585) is:

Age	Thickness, in Feet	Description
Late Pleistocene (?) and Recent	4–5	Alluvium, reddish brown (no kitchen-midden material)
	0–¼	Caliche lens forming locally cemented pockets in underlying stratum
Late Pleistocene	4–5	Gravelly sand, very poorly sorted, abundant cobbles and boulders at base, grading to pebbly sand above, abundant comminuted shell material, whole specimens rare and rendered very brittle because of leaching action of ground water
Cretaceous (Albian)	20 exposed	Volcanic agglomerate composed of angular, well-indurated, tuffaceous blocks

The thin bed of fossiliferous gravel and sand exposed in sea cliffs southeast of Punta Cabras was deposited in 35 feet of water or less (50-foot elevation of shore-line angle less 15-foot average elevation of platform in modern sea cliff). The coarse, poorly sorted aspects of the sediment, together with the small quantity of contained mica and abundance of comminuted shells of shallow-water mollusks, further suggest deposition in very shallow water near shore.

High ratios of calcareous shell material to detrital sediment, also noted at Punta Baja to the south, are indicative of slow rates of deposition. This condition probably is a function of inadequacy in the supply of detrital sediment such as occurs on the outer insular shelves and bank tops of the southern California borderland. There, thin accumulations of white sand composed of Foraminifera and comminuted shells contrast markedly with the thicker gray sand and silty sand, deficient in calcium carbonate, of the coastal shelf near shore. Repeated occurrences of thin sand rich in calcium carbonate on the lowest terrace platform at Punta Cabras and other Baja California localities in a near-shore environment, then, probably reflect a very limited availability of detrital sediment. Locally, the calcium carbonate content may have been enriched in restricted areas of coastal upwelling.[1] The enriched nutrient supply produced by upwelling is known to sustain abnormally high levels of basic organic productivity upon which benthonic invertebrates are ultimately dependent.

Descriptions of Collecting Localities

One of the greatest deterrents to geologic mapping and paleontologic investigation in Baja California is the lack of a suitable base map. The best available base for field plotting of localities was a large-scale sailing chart, the United States Navy Hydrographic Office San Diego to Bahia San Quintin chart, no. 1149, edition 45 (scale 1:290,000). Fossil localities are plotted on an enlarged portion of this map (fig. 2). Subsequent to the writers' field work in this area, Oakes (MS) surveyed the topography of a small area southeast of Punta Cabras. The location of collections plotted on this map, reproduced in figure 3, can be considered accurate. Locality numbers refer to collections contained in the Museum of Paleontology, University of California, Berkeley, California.

A-9585: Latitude 31° 21′ 08″ N., longitude 116° 28′ 20″ W. Sea cliff about 2000 feet southeast of most westerly point on prominent headland between Punta Cabras and Punta Piedras to the north. Four to 5 feet of unconsolidated, gravelly sand containing abundant cobbles and pebbles at basal contact with Cretaceous agglomerate (Alisitos or San Fernando formation). Sand is poorly sorted and contains abundant comminuted shell material. Edge of wave-cut platform is exposed in sea cliff located about 20 feet above a shingle beach. Marine bed is overlain by 5 feet of reddish brown

[1] A large area of shell sand in San Cristobal Bay, Baja California (latitude 27° 25′ N.), in which the calcium carbonate percentage is greater than 50 per cent is more or less coincident with a restricted area of upwelling (Emery *et al.*, 1957).

alluvium with a 2-inch seam of caliche at the base. Collected by W. K. Emerson, June, 1954.

A-9587: Latitude 31° 19′ 58″ N., longitude 116° 27′ 15″ W. Basal marine terrace deposits exposed in face of sea cliff one-half mile east of Punta Cabras. White, well-indurated, sandy coquina of broken mollusk shells 4 feet thick overlying interbedded brown sandstone and pebble conglomerate of the upper Cretaceous Rosario formation. The deposit contains well-rounded boulders ranging up to 1½ feet in diameter at the base. Locally, poorly consolidated marine and alluvial deposits have been stripped away from the edge of the sea cliff, exposing the surface of the terrace platform at an elevation of 12–15 feet above sea level. Collected by W. O. Addicott, February, 1953, and W. K. Emerson, November, 1953.

A-9589: Latitude 31° 20′ 50″ N., longitude 116° 27′ 30″ W. In sea cliff opposite "landing place" notation on sailing chart, immediately northwest of Punta Cabras. Collection from lenses of well-sorted, very fine-grained sand occurring in bed of well-indurated conglomerate overlying massive Rosario sandstone. Marine stratum is overlain by about 30 feet of wind-blown sand. Collected by W. O. Addicott, February, 1953.

A-9713: Approximately 1000 feet south-southeast of A-9917. Abundantly fossiliferous calcareous sandstone containing well-rounded cobbles and boulders of upper Cretaceous sandstone at the base. Several feet of terrace deposits have been stripped away from the wave-cut platform, as shown in the foreground of figure 5. Collected by W. K. Emerson, November, 1953.

A-9917: Approximately 2400 feet south-southeast of A-9587. On the south side of a prominent gully which cuts old road bed. Six- to 12-inch bed of abundantly fossiliferous, poorly consolidated sand lying unconformably upon gently dipping sandstone of the Rosario formation. Sand is overlain by 2 to 4 feet of pebble and boulder conglomerate. Above the conglomerate is a 6-inch layer of midden containing mollusks. The terrace deposits are capped by 6 to 8 feet of red, sandy alluvium and soil. Collected by W. K. Emerson, November, 1953.

A-6289: Pleistocene invertebrates collected by M. V. Kirk and J. R. MacIntyre, in the Punta San Isidro area, Baja California, February, 1950: "Fossiliferous Pleistocene sediment resting on basalts, *etc.*, just north of thin bedded green and buff tuffs above locality A-6285. [A-6285 = Rudistids and corals from limestone reefs below thin tuffs ¾ mile north of small stream which lies about 1 mile north of Punta San Isidro. Alisitos formation, 'Cenomanian,' Upper Cretaceous]."

COMPOSITION OF THE PUNTA CABRAS FAUNA

Collections from five stations yielded a total of 104 metazoan species, including 99 mollusks, two echinoids, two barnacles, and one bryozoan. The Punta Cabras fauna is recorded by localities in table 1. In addition, Kirk and MacIntyre (1951), in their study of the Cretaceous stratigraphy of the area, made an incidental collection of 44 species of invertebrates from the lowest terrace deposit nearly 3 miles southeast of Punta Cabras (locality A-6289). Of this number, three species of

TABLE 1

CHECK LIST OF THE PUNTA CABRAS FAUNA

	Locality Nos.				
	A-9585	A-9589	A-9587	A-9917	A-9713
GASTROPODA					
Acanthina lugubris (Sowerby, 1821)	—	—	x	x	x
Acanthina spirata (Blainville, 1832)	—	—	—	x	x
Acmaea digitalis Eschscholtz, 1833	—	—	x	—	x
Acmaea insessa (Hinds, 1842)	—	—	x	—	—
Acmaea mitra Eschscholtz, 1833	x	—	x	—	x
Acmaea pelta Eschscholtz, 1833	x	—	x	—	x
Acmaea scabra (Gould, 1846)	—	—	x	—	x
Acmaea cf. *A. scutum* Eschscholtz, 1833	x	—	—	—	—
Aletes squamigerus Carpenter, 1856	—	x	—	—	—
Amphissa versicolor Dall, 1871	x	x	x	x	x
Bursa californica Hinds, 1843	x	—	x	—	—
Calliostoma ligatum Gould, 1852	x	x	x	—	—
Clathrodrilla incisa ophioderma (Dall, 1908)	—	—	x	—	x
Clathrodrilla incisa cf. *C. i. fancherae* (Dall, 1903)	x	—	x	—	x
Conus californicus Hinds, 1844	x	x	x	—	x
Crepidula adunca Sowerby, 1824	—	x	—	x	x
Crepidula lingulata Gould, 1846	—	x	—	—	—
Crepidula nivea C. B. Adams, 1852	—	—	x	—	—
Crepidula cf. *C. norrisianum* Williamson, 1905	x	x	—	—	—
Crepidula onyx Sowerby, 1824	—	—	x	—	—
Cymatosyrinx hemphilli (Stearns, 1871)	—	—	x	x	x
Diodora aspera (Eschscholtz, 1833)	—	x	x	—	x
Epitonium indianorum (Carpenter, 1864)	—	—	x	—	—
Fissurella volcano Reeve, 1849	—	—	x	—	—
Gadinia reticulata (Sowerby, 1835)	—	—	x	—	x
Haliotis cracherodi Leach, 1814	x	—	—	—	—
Hipponix antiquatus (Linnaeus, 1767)	x	x	x	—	x
Hipponix tumens Carpenter, 1864	x	—	—	—	—
Homalopoma cf. *H. carpenteri* (Pilsbry, 1888)	—	x	—	—	—
Jaton festiva (Hinds, 1844)	x	—	x	—	—
Kelletia kelleti (Forbes, 1850)	x	—	x	x	x
Lamellaria cf. *L. diegoënsis* Dall, 1885	—	—	—	—	x
Littorina planaxis Philippi, 1847	—	—	—	—	x
Littorina scutulata Gould, 1849	—	x	x	—	x
Lottia gigantea Sowerby, 1834	—	x	—	—	—
Mangelia aff. *M. variegata* Carpenter, 1864	—	—	x	—	—

TABLE 1—(*Continued*)

	Locality Nos.				
	A-9585	A-9589	A-9587	A-9917	A-9713
Maxwellia gemma (Sowerby, 1879)	—	—	x	—	—
Mitra idae Melville, 1893	x	—	?	—	—
Mitrella carinata (Hinds, 1844)	x	x	x	—	x
Mitrella carinata forma *gausapata* (Gould, 1851)	—	x	—	—	x
Mitrella tuberosa (Carpenter, 1864)	—	—	—	—	x
Nassarius delosi (Woodring, 1946)	x	—	x	x	x
Nassarius fossatus (Gould, 1849)	x	x	x	x	x
Nassarius mendicus (Gould, 1849)	x	x	x	—	x
Nassarius mendicus forma *cooperi* (Forbes, 1850)	—	—	x	—	—
Nassarius perpingus (Hinds, 1844)	x	x	x	x	x
Ocenebra lurida Middendorff, 1848	x	—	x	—	x
Olivella biplicata (Sowerby, 1825)	x	x	x	x	x
Olivella pedroana "Conrad" Woodring, 1946	x	—	x	x	x
Opalia wroblewskyi chacei Strong, 1937	—	—	—	—	x
Polinices lewisi (Gould, 1847)	x	x	x	?	?
Polinices cf. *P. reclusianus* (Deshayes, 1839)	x	—	—	?	?
Pseudomelatoma torsa (Carpenter, 1864)	—	—	—	—	x
"*Purpura*" *nuttalli* var. *aciculiger* (Valenciennes, 1846)	—	—	x	—	—
Pusula californianus (Gray, 1863)	x	—	x	x	—
Seila montereyensis Bartsch, 1907	—	—	x	—	—
Tegula brunnea (Philippi, 1848)	x	?	x	—	—
Tegula funebralis (A. Adams, 1854)	x	—	x	—	x
Tegula cf. *T. gallina* (Forbes, 1850)	x	—	?	—	—
Tegula ligulata (Menke, 1850)	—	—	x	—	—
"*Tegula*" *montereyi* (Fischer, 1880)	—	x	—	—	—
Tegula pulligo (Gmelin, 1790)	—	x	—	—	—
Terebra pedroana Dall, 1908	x	—	x	x	x
Thais haemastoma biserialis (Blainville, 1832)	x	—	—	—	—
Thais emarginata (Deshayes, 1839)	x	—	x	—	x
Turritella cooperi Carpenter, 1864	—	—	—	—	x
Vitrinella stearnsi Bartsch, 1907	—	x	—	—	—
SCAPHOPODA					
Dentalium neohexagonum Sharp and Pilsbry, 1897	x	x	x	x	x

TABLE 1—(*Continued*)

	Locality Nos.				
	A-9585	A-9589	A-9587	A-9917	A-9713
AMPHINEURA					
Cryptochiton stelleri (Middendorff, 1846)	x	—	x	—	—
PELECYPODA					
Anomia peruviana d'Orbigny, 1846	—	x	—	—	—
Chama pellucida Broderip, 1835	x	—	—	—	—
Cryptomya californica (Conrad, 1837)	—	x	—	—	x
Cumingia californica (Conrad, 1837)	—	x	—	—	—
Donax gouldi Dall, 1921	—	—	x	—	—
Here exacavata (Carpenter, 1857)	x	—	—	—	—
Hinnites multirugosus (Gale, 1928)	x	x	—	—	—
Leptopecten latiauratus (Conrad, 1837)	x	—	—	—	—
Leptopecten latiauratus monotimeris (Conrad, 1837)	—	—	x	—	x
Lucina californica Conrad, 1837	x	—	—	—	—
Lucina nuttalli Conrad, 1837	x	—	x	x	x
Macoma nasuta forma *kelseyi* Dall, 1900	x	—	—	—	—
Modiolus fornicatus (Carpenter, 1864)	—	x	x	—	—
Mytilus californianus Conrad, 1837	x	x	x	—	x
Nuculana taphria (Dall, 1896)	x	—	x	x	x
Penitella cf. *P. penita* (Conrad, 1837)	—	—	x	—	—
Petricola carditoides (Conrad, 1837)	x	x	x	—	x
Pododesmus machroschismus (Deshayes, 1839)	—	x	x	—	—
Protothaca staminea (Conrad, 1837)	—	x	x	x	x
Saxidomus nuttalli (Conrad, 1837)	—	x	—	—	—
Schizothaerus nuttalli (Conrad, 1837)	x	—	x	x	x
Semele decisa (Conrad, 1837)	x	—	—	—	—
Septifer bifurcatus (Conrad, 1837)	—	—	x	—	—
Solen sicarius Gould, 1850	—	x	—	—	—
Tellina bodegensis Hinds, 1844	—	x	x	—	x
Tellina buttoni Dall, 1900	—	—	x	—	—
Tivela stultorum (Mawe, 1823)	—	x	x	—	—
Trachycardium cf. *T. quadragenarium* (Conrad, 1837)	—	—	x	—	—
Transennella tantilla (Gould, 1853)	—	x	—	—	—
Zirfaea pilsbryi Lowe, 1931	—	?	x	x	x
ECHINOIDEA					
Dendraster excentricus (Eschscholtz, 1831)	—	x	—	—	—
Strongylocentrotus sp.	—	x	—	—	—

TABLE 1—(*Continued*)

	Locality Nos.				
	A-9585	A-9589	A-9587	A-9917	A-9713
CIRRIPEDIA					
Balanus cf. *B. nubilus* Darwin, 1854	x	x	x	—	—
Balanus cf. *B. tintinnabulum californicus* Pilsbry, 1916	—	x	x	—	—
BRYOZOA					
Schizoporella cornuta (Gabb and Horn, 1862)	—	x	—	—	—

mollusks, namely, *"Mangelia" barbarensis* Oldroyd, 1924, *Glycymeris ?profunda* Dall, 1879, and *Macoma acolasta* Dall, 1921, were not taken from the five stations of the present writers. Paleoecological interpretations are thus based on a collected fauna totaling 107 species of metazoan invertebrates, of which 11 are questionably identified. No particular attempt was made to procure minute organisms.

One species, *Lamellaria diegoënsis,* is here recorded for the first time as a fossil. Only one extinct species was recognized in the fauna. This pelecypod, *Macoma acolasta,* was described by Dall (1921) from the late Pleistocene fauna at San Quintín Bay and is also recorded from terrace deposits of a similar age at Goleta, California (Grant and Gale, 1931). The fauna therefore is essentially modern in composition.

HABITAT REQUIREMENTS

Ecologic interpretations of Pleistocene benthonic invertebrate faunas can be drawn through comparisons with the known bathymetric distribution and substrate affinities of the species. Although the collections from localities A-9585, A-9587, and A-9713 contain a larger number of species requiring a rocky substrate than those from localities A-9589 and A-9917, differences in composition may reflect, in large part, local conditions of preservation and selective field collecting. The composition of five assemblages, however, is similar enough in ecological aspects to permit discussion of them as a unit. Taken as a whole, approximately 60 per cent of the fauna are rock or rock-rubble inhabitants, and the remainder are sand dwellers or ecologically ubiquitous forms.

All constituents of the fauna may occur at the present time in shal-

low water along an exposed coast. More than 50 per cent of the fauna inhabit rocks or rocky rubble in the intertidal zone or shallow infratidal waters which are subject to some wave action. A small element, including *Tivela stultorum* and *Donax gouldi*, live in exposed sandy beaches of the shallow littoral or intertidal zones. Other species, including *Lucina californica*, *Protothaca staminea*, *Olivella biplicata*, and *Nassarius* spp., may occur in shallow water of exposed coasts in patches of sand partially protected by boulders. The second largest element in

FIG. 6. Sea cliff immediately south of locality A-9713, showing contact with basal conglomerate of rounded Cretaceous sandstone boulders. Boulders attain more than 2 feet in diameter (note 12-inch pick in center of photograph).

the fauna, totaling about 30 per cent, is composed of ecologically wide-ranging species which can live either in quiet water of protected bays or in shallow depths below strong wave action off exposed coasts.

ENVIRONMENT OF DEPOSITION

None of the faunal constituents requires a bathymetric environment greater than 10 fathoms, and most of the components occur in shallower depths. Specimens of the minor, deeper water element in the fauna are largely fragmental and worn; they undoubtedly were transported shoreward by storm waves. The inferred paleoecological requirements thus serve to corroborate the previously mentioned

evidence of terrace physiography and sediment composition which suggest that deposition occurred in shallow waters of depths not greater than 30 to 35 feet (p. 12).

Both the faunistic and depositional data, therefore, indicate that the Pleistocene coastal topography was essentially the same as the topography that exists today along this coast, where the headlands divide the shore into areas of rocky reefs and intervening sandy beaches.

Temperature Requirements

Although the Punta Cabras fauna is distinctively modern in composition, it contains a conspicuous "northern" element comprising species which are now locally extinct. These 17 species, all of which are mollusks, are restricted in distribution at the present time to points north of latitude 31° 20″ N. (see table 2). The presence of this shallow-water, northern element, together with the occurrence of only one southern, warm-water species,[1] indicates that a colder hydroclimate existed at this depositional site than now exists at this latitude. The southward-ranging, warm-water species suggests that water warmer than that at present also occurred at least locally in the vicinity.

Brief mention should be made of recently developed geochemical techniques for the evaluation of the values of temperature to shell growth in carbonate-secreting organisms. Detailed quantitative studies of the isotopic abundances of the O^{16}/O^{18} ratios (Urey *et al.*, 1951) and the aragonite-calcite ratios (Lowenstam, 1954) of skeletal remains of these creatures should complement and refine present paleo-temperature interpretations based largely on the geographic ranges of the living components of the Pleistocene faunas. Although no oxygen isotope data are available for the faunas concerned here, Emiliani and Epstein (1953) report a temperature range of 12° C. to 30° C. for Foram-

[1] One incomplete specimen of *Thais haemastoma biserialis* (Blainville) was collected at locality A-9585. Although this species is recorded to range from San Diego southward to Peru (Dall, 1923), the northern occurrence was based on one report of the collection of "A single living specimen from the beach north of False Bay [Mission Bay], near La Hoya [La Jolla, California]" (Orcutt, 1885. p. 535). Actually, this species does not appear to live at the present time north of Lagoon Head (latitude 28° 15′ N.) in Sebastian Vizcaino Bay, Baja California (Chace, 1958, *in litt.*). It is recorded from five Pleistocene terrace deposits along the Baja California coast: Punta Descanso (Valentine, 1957), Cedros Island (Hertlein, 1934), Turtle Bay (Chace, 1956), San Ignacio Lagoon (Hertlein, 1934), and Magdalena Bay (Jordan, 1924; and others); it also occurs in the Palos Verdes sand of the Los Angeles embayment (Woodring *et al.*, 1946).

TABLE 2

LOCALLY EXTINCT "NORTHERN" SPECIES OF MOLLUSKS IN THE PUNTA CABRAS FAUNA, WITH MODERN SOUTHERN END POINT OF RANGE INDICATED

GASTROPODA	
Acmaea mitra	Punta Santo Tomás, Baja California
Acmaea scutum	Santa Barbara, California
Calliostoma ligatum	San Luis Obispo Co., California
Crepidula norrisianum	San Pedro, California
Epitonium indianorum	Todos Santos Bay, Baja California
Mitra idae	Cortes Bank, off San Diego, California
Nassarius delosi	Balboa Beach, California
Nassarius mendicus forma *cooperi*	San Diego, California
Ocinebra lurida	Santa Catalina Island, California
Opalia wroblewskyi chacei	San Diego, California
Polinices lewisi	Todos Santos Bay, Baja California
Tegula brunnea	Santa Barbara Islands, California
"*Tegula*" *montereyi*	Santa Barbara Islands, California
Vitrinella stearnsi	Off South Coronado Island, Baja California
AMPHINEURA	
Crypotochiton stelleri	Monterey County, California
PELECYPODA	
Macoma acolasta[a]	[San Quintín Bay, Baja California, Pleistocene]
Macoma nasuta forma *kelseyi*	Puget Sound, Washington

[a] This species is not known to be living, but is considered by Grant and Gale (1931) to be a variety of the circumboreal species *Macoma moesta* Deshayes, 1854.

inifera tests from the early Pleistocene Lomita marl of San Pedro, California. Urey and his co-authors (*in* Suess, 1954) record oxygen-18 temperature values for single species of mollusks from five kitchen-midden sites along the northwestern coast of Baja California. These analyses, together with radiocarbon data, indicate that measurable changes of ocean temperatures have occurred recently along this coast (see table 3). The findings are corroborated by the present distribution and the known temperature requirements of the organisms that comprise the samples.

CLIMATIC SIGNIFICANCE

In order to evaluate the thermal significance of the Punta Cabras assemblage, it is necessary to consider briefly the composition of the regional late Pleistocene faunas. Mention is made above of the presence along the northwestern Baja California coast of presumably cor-

relative late Pleistocene faunas representing two ecologically diverse facies: (1) predominantly cool-water, open-coast assemblages, and (2) a warm-water, protected-bay assemblage. Open-coast faunas are known from the Punta Descanso area (latitude 32° 16′ N.), Punta China (31° 31′ N.), the presently considered area (31° 20′ N.), and Punta Baja (29° 57′ N.). The protected-bay facies is reported in this region from only one area, San Quintín Bay (latitude 30° 21′ N.); for reference to the localities see figure 1. Thus the contemporaneous existence of tropical elements in the semi-protected San Quintín embayment and boreal ele-

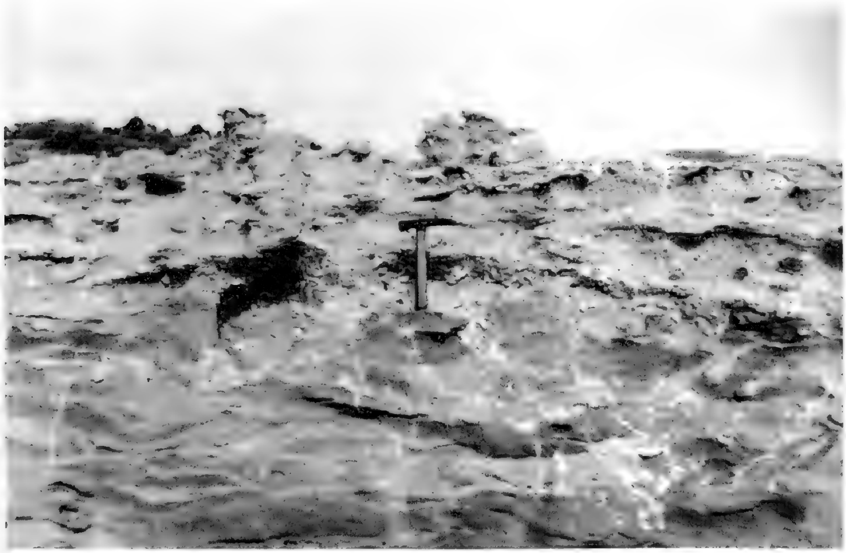

FIG. 7. Detail of late Pleistocene coquina and contact with upper Cretaceous sandstone in sea cliff east of Punta Cabras (locality A-9587).

ments along the open coast is indicated by the composition of these fossil faunas. To the north, a similar distributional pattern occurs in the apparently correlative late Pleistocene faunas of the Palos Verdes sand in the Los Angeles basin and in the Bay Point formation of the San Diego area. Within these former embayments, a lateral change in the composition of the faunas appears to be controlled largely by the location of the assemblages in relation to temperature as against habitat requirements. Protected, back-bay environments of the late Pleistocene were dominated by warm-water elements, intermediately situated localities by "mixed assemblages," and unprotected, open-coast environments by cool-water elements (Emerson, 1956b).

An explanation to account for the apparent thermal diversity exhibited by composition of these faunas has been recently proposed. It is postulated that during the late Pleistocene a contemporaneous distribution of shallow, in-shore waters, both colder and warmer than those that now exist in this region, allowed marine organisms that are at present geographically or bathymetrically separated to live in close proximity. Valentine (1955) believes that the colder water resulted chiefly from southward-flowing currents and from upwelling, and that the warmer water was derived largely from solar heating of shallow waters in protected areas and by introduction of warm, northward-flowing countercurrents. A general warming of the oceanic waters by an increase in solar radiation was also suggested, but the required thermal diversity to support contemporaneous cool- and warm-water faunas was considered as possibly resulting from "increased oceanic and atmospheric circulation during glacial times" (Valentine, 1957). Regardless of the phenomena involved, temperatures warmer and colder than those that exist at the present time in this region would be required to support the different ecological facies compromising the correlative late Pleistocene faunas of southern and peninsular California.

Although it appears probable that increased rates of near-shore upwelling, together with a minor northern shift of isotherms, were major factors in producing the late Pleistocene hydroclimate, it seems likely that the thermally "anomalous" assemblages existed contemporaneously only in the vicinity of protected or semi-protected embayments. An examination of the local distribution of the ecologically diverse elements in the four open-coast, predominantly cool-water faunas indicates that the cold-water species appear in collecting stations to the north of the old headlands as well as to the south, and the species representing the minor, warm-water element are not necessarily restricted to northerly situated depositional sites. Thus, the location of intense areas of local upwelling on the south sides of the late Pleistocene promontories is not reflected in the composition of the fossil faunas, and the antiquity of the present upwelling sites in these areas has yet to be unequivocally demonstrated (Emerson, 1956a).

The present distribution of the shallow-water, marine, benthonic organisms in the southern half of Pacific Baja California appears nearly to parallel conditions that existed along the late Pleistocene coast of northern peninsular and southern California. In this region, the geographically discontinuous pattern of water temperatures is reflected by the presence of tropical elements in the shallow, warm-water lagoons and protected bays, warm-temperate assemblages in

adjacent open-coast waters, and "northern" species in coastal areas of seasonal upwelling (Emerson, 1956b).

DATE OF PLATFORM CUTTING AND AGE OF MARINE DEPOSITS

Evidence bearing upon the late Pleistocene age of the Punta Cabras platform and its veneer of marine sand and gravel is furnished by paleontologic comparisons, carbon isotope determinations, and physiographic relationships. The last two lines of evidence are of regional scope. They are based on two premises: (1) that cutting of the Punta Cabras and correlative terraces, submarine terraces, and buried stream channels was controlled by eustatic shifts in sea level, and (2) that these features may be correlated on a regional scale. The reader is referred to Flint (1957, pp. 258–259) for a discussion of factors modifying the theory of climatic control of sea level during Pleistocene glaciation. Despite evidence of slight regional warping (Emery, 1958) and gentle local deformation (Poland *et al.*, 1956) of certain late Pleistocene wave-cut surfaces, there is good reason to believe that many of these features can be correlated.[1]

PALEONTOLOGIC EVIDENCE

The composition of the Punta Cabras fauna compared with the Pacific coast Cenozoic stages based on the metazoan chronology (Weaver *et al.*, 1944) requires a post early Pleistocene age assignment. Faunistic comparisons with the regional type section at San Pedro (Woodring *et al.*, 1946) suggest correlation with the late Pleistocene Palos Verdes sand (upper San Pedro series). Similar, essentially modern assemblages representing a comparable shallow-water, open-coast facies are known to occur in presumably correlative deposits of the Bay Point formation at San Diego, California, as well as elsewhere along the northwestern Baja California coast as far south as latitude 29° 57′ N.

Regardless of the distinctive modern aspect of the Punta Cabras fauna, the presence of species not now living at this latitude reflects a significant change in the local hydroclimate since deposition of the assemblage. Viewed on a regional basis, the number of locally extinct

[1] Emery (1958) has identified and correlated five submerged terraces from the continental borderland adjoining the southern California coast (latitudes 32°–34.5° N.). Several alluvium-filled river valleys in coastal southern California have "bedrock" floors graded to a lowered late Pleistocene sea level. Depths to these surfaces, determined by water-well borings along the modern coast line, appear to be correlative, occurring regularly between about 150 and 200 feet (Upson, 1949).

faunal components would seem to be sufficient evidence alone to preclude the assignment of a post-Wisconsin age to the assemblage. Minor changes in the distribution of some components of the regional Recent fauna obviously have occurred, with temporal fluctuations of marine isotherms and locally controlled hydrographic changes, but these thermal variations appear to have been of considerably less magnitude than those of pre-Wisconsin time. The invertebrates found in kitchen middens of the region, with the exception of one or two constituents, are species now found living in the vicinity of the sites. Some midden accumulations reflect unstable local environmental conditions which are expressed by vertical changes in specific composition and by the presence in different midden levels of the same species represented by distinctive habitat variants, e.g., ecophenotypic examples of the pismo clam, *Tivela stultorum*.

In passing, mention should be made of the occurrence of extinct Pleistocene vertebrates in non-marine alluvial fans capping marine deposits on the lowest exposed terraces in southern California and on Santa Rosa Island.

Physiographic Evidence

Differentiation of late Pleistocene deposits from Recent ones based on percentages of extinction of marine invertebrates is not possible, because significant evolutionary changes in this group cannot be demonstrated during this span of geologic time. In addition, coastal deposits generally believed to be of Recent age are invariably non-marine. A satisfactory boundary proposed by Read (Russell, 1957), based on physiographic and depositional evidence, can be placed at the time when the greatly lowered late Pleistocene sea level began its last rise to the present-day level. This event is well recorded by development of two kinds of erosional surfaces at the margins of continents: (1) the submerged, wave-cut platform at the edge of the continental shelf, the 250–300-foot shelf-break off the southern California coast, and (2) the subaerially eroded bedrock surfaces of river and stream channels lying 150–300 feet below sea level near modern coast lines (Flint, 1957). Conclusive world-wide correlation of these features is seriously hampered by gentle crustal warping, although regional correlations are possible. Fortunately, this event falls within the range of the carbon-isotope dating technique, and an absolute age chronology is being developed.

Reconnaissance investigation of the lowest exposed marine terrace along the northwest coast of Baja California indicates that the initial

seaward slope of platform surfaces has not been modified by deformation. Shore-line angles of these terraces appear to be correlative, occurring within a range of 50 to 100 feet in elevation over a distance of at least 200 miles. At the international boundary, nearly 100 miles northwest of Punta Cabras, the apparently correlative Nestor Terrace is truncated by the late Pleistocene channel of the Tijuana River (Emerson and Addicott, 1953). Water wells drilled in other ancestral river channels in the coastal San Diego area (Ellis and Lee, 1919) and Los Angeles basin (Poland *et al.*, 1956) logged "bedrock" surfaces at depths of up to 150 feet below sea level. River channels were cut into strata as young as lower Pleistocene in the Los Angeles basin. There can be little doubt that the controlling base level of the ancestral Santa Ana and San Gabriel rivers (Poland *et al.*, 1956) was a greatly lowered late Pleistocene shore line. This shore line is probably recorded by the edge of the extensive wave-cut platform lying at a depth of about 250 feet off the Los Angeles basin. It is believed that this lowered sea level was eustatic and developed in response to the maximum spread of continental ice during the Wisconsin ice age. Following this still-stand, a rising sea level associated with climatic amelioration permitted the accumulation of Recent channel and flood-plain deposits by alluvial aggradation to present levels.

Radiocarbon Evidence

A number of archeological samples from West Coast alluvial sites have been dated by carbon-14 methods. Data are available for localities in California at Santa Rosa Island (Orr, 1956; Broecker and Kulp, 1957), La Jolla and San Diego (Rubin and Suess, 1955; Broecker and Kulp, 1957; Kulp, *in* Carter, 1957), and along the northwestern coast of Baja California (Suess, 1954). These samples reveal extremes of ages from a low of 300 ± 160 years for shells of *Tivela stultorum* taken from surface sand dunes near the beach at San Antonio del Mar, Baja California (Suess, 1954), to a high of greater than 33,000 years for calcareous sand (land shells) from 40 feet below the surface of a 50-foot-thick alluvial fan capping a marine terrace 10 to 25 feet in height on Santa Rosa Island, California (Broecker and Kulp, 1957). At the controversial Texas Street site in the San Diego River Valley, "hearth" charcoal, considered by Carter (1957) to date from the third interglacial stage, was found to be older than 35,000 years (Broecker and Kulp, 1957).

A close correlation between relative age and vertical succession of samples in kitchen middens has been demonstrated in material from

TABLE 3

RADIOCARBON MEASUREMENTS AND OXYGEN-18 DETERMINATIONS OF ARCHEOLOGICAL SAMPLES FROM NORTHWESTERN BAJA CALIFORNIA, MEXICO
(Data after Suess, 1954, pp. 467–468.)

Nature of Sample	Locality Description	Depth in Feet Below Surface	C-14 Ages in Years	O-18 Determinations
Tivela stultorum, small, warm-water variety. From thin, surface middens (*fide* Carter, 1957, p. 133); W-29	Socorro Cañon, near San Quintín Bay	0	330±160	17.8°C.
Tivela stultorum, small, warm-water variety. From thin, surface middens on sand dunes (*fide* Carter, 1957, p. 133); W-31	San Antonio del Mar, (Johnson Ranch)	0	300±160	18.2°C.
Cryptochiton stelleri, cold-water indicator, southern end point of present range is Monterey, California. From midden; W-32	Rosario Cañon, north of Punta Baja	2	650±200	16.7°C.
Mytilus californianus. From midden; W-26	Between Punta Cabras and Punta San Isidro	3–4	2540±200	17.1°C.
Mytilus californianus. From sand dune midden with definite hearth, resting on a "Pleistocene shell beach" (*fide* Carter, 1957, p. 134); W-30	Punta Baja	5	4030±200	17.1°C.

Baja California assembled by Dr. Carl L. Hubbs. These data are here tabulated in table 3. Comparable findings are recorded by Orr (1956) for wood and archeological samples from an alluvial fan covering a marine terrace platform 10 to 25 feet in height on Santa Rosa Island, California. Samples of wood associated with mammoth bones taken from a depth of 40± feet below the alluvial surface dated 15,820±280 years, while a sample of charred mammoth bone from 37.5 feet above the base of the alluvium yielded values averaging 29,700±3,000 years. These Wisconsin age sites cover marine beds referable to the third interglacial stage (Carter, 1957).

FIG. 8. View northeast from locality A-9587. Wave-cut terrace platform visible in center foreground and to the right. Bedding in underlying Rosario sandstone is essentially horizontal.

More pertinent to the present study are age measurements of samples from the alluvial cover of the lowest exposed marine terraces of coastal southern and peninsular California. Carter (1957) described a sand dune 8 feet in thickness that covered a "Pleistocene shell beach"[1] at Punta Baja, Baja California. This sand mantle was dated as 4000± years in age by mussel shells from a hearth situated 4 feet below the surface of the dune (Suess, 1954, sample W-30). Carter (1957), who has made a detailed geomorphologic study of the Quaternary history of the La Jolla embayment, records significant age data for the alluvial

[1] Undoubtedly the Punta Baja terrace platform which is exposed in the present sea cliff at an elevation of 12 to 15 feet above sea level (Emerson and Addicott, 1958).

fan covering a marine terrace platform 25 feet in height exposed in the sea cliff near the Scripps Institution of Oceanography. Charcoal of possible hearth origin from a depth of 13 feet below the surface of a midden in the alluvial cover yielded an age of 21,500±700 years. Mussel shells and charcoal from a hearth situated in a recently cut gully fill in the fan were found to date 580±200 and 600±200 years, respectively (Rubin and Suess, 1955). The platforms at these localities are presumed to be correlative with the Punta Cabras terrace platform.

Two samples of shell material from late Pleistocene deposits on the lowest marine terrace at San Pedro, California (Kulp *et al.*, 1952), and Santa Cruz, California (Bradley, 1956), gave carbon-14 age determinations of more than 30,000 years and 39,000 years, respectively.

Cores of unconsolidated submarine deposits associated with the —250-foot terrace off San Pedro, California (Emery, 1958), have yielded specimens of calcareous algae which show no evidence of transport. The occurrence of these shallow-water, euphotic-zone specimens, *in situ,* below the fore edge of the 250-foot submarine terrace is further evidence of a greatly lowered sea level. Carbon-14 dates of 17,900 to 24,500 years on these specimens correspond closely to the 18,000-year date for the maximum development of continental ice during the Wisconsin glacial age (Suess, 1956). This evidence lends support to the belief that the ancestral river channels were eroded during the late Pleistocene glacial maximum.

To summarize, limited carbon-14 measurements indicate that the youngest (lowest) exposed terraces of marine origin in this region are older than 35,000± years and beyond the present range of this dating technique. Additionally, alluvial covers of these terrace deposits have yielded dates up to 33,000± years. The carbon-14 dates of soil profiles show increasing age with increasing depths and require a Wisconsin age assignment for much of the alluvium. This and the faunistic evidence suggest a pre-Wisconsin origin for these terrace deposits.

Conclusion

The Punta Cabras fauna is distinctly modern in aspect, as are the assemblages from the other low-lying terraces of this region, and indicates a post early Pleistocene age assignment. All available data concerning the lowest terraces along the northwest coast of Baja California, although admittedly scant at present, point to correlation of the Punta Cabras platform and associated marine deposits with the Nestor terrace of the San Diego region. If this correlation is valid, the Punta Cabras terrace was developed prior to erosion of alluvium-filled

river valleys lying some 100 miles to the northwest. These river channels were graded to a greatly lowered sea level which developed during the late Pleistocene Wisconsin ice age. Therefore, the date of the Punta Cabras platform cutting and the age of associated marine deposits are assumed to be post early Pleistocene, pre-Wisconsin.

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